**KIBABII UNIVERSITY**

**UNIVERSITY EXAMINATIONS**
**2021/2022 ACADEMIC YEAR**

**THIRD YEAR SECOND SEMESTER**
**MAIN EXAMINATIONS**

**FOR THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY AND BIO FUELS TECHNOLOGY**

**COURSE CODE:** **REN 321**

**COURSE TITLE:** **SOLAR ENERGY II**

DURATION: **2 HOURS**

**DATE: 06/09/2022** **TIME: 2:00PM-4:00PM**

**INSTRUCTIONS TO CANDIDATES**

- Answer **QUESTION ONE** (Compulsory) and any other TW**O** (2) Questions.
- Indicate **answered questions** on the front cover.
- Start every question on a new page and make sure question's number is written on each page.

This paper consists of **4** printed pages. Please Turn Over

**Question One**

(a) (i) List the main process steps involved in the manufacture of multi-crystalline silicon wafers from polysilicon feedstock [ 2 marks]

(ii) Describe the process sequence in a typical manufacturing process for "conventional" crystalline silicon cells (i.e., cells with screen printed contacts on multi-crystalline silicon wafers and explain briefly the purpose of each process step. [ 3 marks]

(iii) Explain the additional process steps that can be applied to mono-crystalline wafers to increase the efficiency of "conventional" solar cells. [ 2 marks]

(iv) List the key process steps that contribute to the high cell efficiency in the manufacture of high efficiency "laser grooved buried grid" crystalline silicon solar cells and state what benefit each step provides. [ 2 marks]

(b) (i) List the process steps in the production of thin film solar cells that are common to all technologies that use glass substrates [ 3 marks]

(ii) Explain why optimisation of the thickness of the I-layer in p-i-n amorphous silicon solar cell is important in terms of cell performance. How have cell designs developed based on this optimization and what implications has this had for the manufacturing process? [ 5 marks]

(c) (i) In a manufacturing plant with a nominal production capacity of $400{,}000 m^2$/shift/year what would be the plant output in MW in the first year of operation if it was operating at two shifts/day, the plant up-time was 90%, the process yield was 95% and average module efficiency was 8%? (Show your calculations clearly) [ 5 marks]

(ii) If the variable cost of product in year one was $\$80/m^2$, what would be the variable cost of product expressed in units of \$/W? (Show your calculations) [ 3 marks]

(d) Draw and label a sketch of the main components of a crystalline silicon PV module [ 5 marks]

**Question Two**

A photovoltaic converter system is required for use in a single-phase small-scale connected application.

(a) With the aid of a suitable block and/or circuit diagrams, describe three PWM converter systems that can be used to interface the PV array to the grid. [ 12 marks]

**(b)** Give the advantages of each scheme. [4 marks]

**(c)** Discuss the factors to be considered in the design of controllers for such an application [4 marks]

**Question Three**

(i) Mismatch losses are a major reason why PV systems often perform less than expected. Explain how such losses arise, making use of IV curves to illustrate what happens when modules are connected in arrays. Describe the various approaches that can be taken to minimize these array losses **[10 marks]**

(ii) Explain why Maximum Power Point Tracking is important and how power electronics is used to achieve it in the case of grid-connected PV systems **[5 marks]**

(iii) Comment on the need for anti-islanding protection for grid-connected inverters. **[5 marks]**

Describe a low-cost technique that can be used to provide reliable protection against this.

**Question Four**

Outline the key steps in the derivation of the ideal I-V characteristic of a p-n junction solar cell, making clear reference to the importance of minority carrier transport and recombination. Any assumptions required for the derivation should be clearly stated. **[ 20 marks]**

**Question Five**

(a) (i) Explain the key differences between off-grid and grid-connected PV systems. **[8 marks]**

Your answer should make reference to the following:

- System sizing methodology
- Relative importance of security of supply
- Difference in component choice
- Mounting detail

A house with intermittent grid supplied electricity has a south facing, tiled roof with an inclination of $30^0$. The roof measures 10m × 5m and there is a chimney measuring 0.5m × 0.5m in the middle of the left wall and which projects 1m above the roof top, but does not take any roof space.

The householder's annual electricity consumption is 2000kWh (with the largest single load of 300W). They would like to remove the dependence on the utility by supplying the current electrical needs with PV, although they do have a limited budget.

(b) Design a PV system for this property, identifying your reasons for making selections between different components (which are detailed below). Assume that the longest period without sun is 4 days and the longest period without the grid is 2 days with a frequency of once per month for both sun and grid although not necessarily at the same time. **[8 marks]**

| | |
|---|---|
| PV module 1: | Framed laminate, 1m×0.5m, $70W_p$, $18V_{pp}$, \$500 |
| PV module 2: | Roof tile, 0.35m×0.25m, $7W_p$, $3V_{pp}$, \$60 |
| Battery 1: | 2V cell, capacity = 450Ah, \$200 |
| Battery 2: | 12V battery, capacity = 100Ah, \$170 |
| Inverter 1: | $P_{ac,max}$ = 500W, $V_{dc}$ = 11-14V, \$600 |
| Inverter 2: | $P_{ac,max}$ = 700W, $V_{dc}$ = 100-200V, \$1500 |
| Inverter 3: | $P_{ac,max}$ = 1000W, $V_{dc}$ = 140-400V, \$1700 |
| Inverter 4: | $P_{ac,max}$ = 3000W, $V_{dc}$ = 22-28V, \$3000 |

(c) What are the advantages and disadvantages of choosing a stand-alone system for this application? **[4 marks]**